Attorney Docket No. ISOT-020

APPLICATION

FOR UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, **Donald D. Tilton**, a citizen of the United States, **Paul A. Knight**, a citizen of Canada, and **David H. Knaggs**, a citizen of the United States, have invented a new and useful liquid thermal management socket system of which the following is a specification:

Liquid Thermal Management Socket System

CROSS REFERENCE TO RELATED APPLICATIONS

Not applicable to this application.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable to this application.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to thermal management systems for electronic devices and more specifically it relates to a liquid thermal management socket system for thermally managing an electronic device in a socket.

Description of the Related Art

Electronic devices removably positioned within sockets have been in use for years. Sockets allow for efficient replacement and upgrading of electronic devices

(e.g. microprocessors). Figure 1b illustrates an exemplary socket unit (14) attached to a circuit board (12) (e.g. motherboard, expansion board) that has a plurality of socket receptacles (15) for receiving the device connectors of an electronic device. Figure 1a illustrates an exemplary configuration of an electronic device (16) coupled to a socket unit (14) with a heat sink (18) thermally coupled to the electronic device by a layer of thermal interface material (17) to allow for air cooling of the electronic device.

While conventional "air cooling" of electronic devices, air cooling is not desired an efficient method of thermally managing modern high-power electronics which have high thermal management requirements. In addition, air cooling is sometimes not capable of adequately thermally managing modern electronic devices with high heat flux areas resulting in reduced efficiency and possibly failure of the electronic device.

Liquid thermal management systems are the most promising technology for thermally managing modern electronic devices. Liquid cold plates, liquid immersion and spray cooling are the three most commonly utilized liquid thermal management systems. Liquid immersion and spray cooling are typically more efficient than liquid cold plates. Liquid immersion involves applying a dielectric liquid coolant directly over one or more electronic devices. Spray cooling involves spraying a dielectric liquid coolant onto one or more electronic devices. An exemplary spray cooling system is described in U.S. Patent No. 5,420,804 to Tilton et al., and is hereby incorporated by reference. Hence, it is desirable to utilize either liquid immersion or spray cooling in the thermal management of modern electronic devices.

While liquid thermal management systems have significant performance advantages over air cooled systems, there are some inherent problems. One of the problems with conventional liquid thermal management systems is that they sometimes require modifications by board manufacturers or electronic device manufacturers. A

further problem with conventional liquid thermal management systems is that they are not easily integrated within the form factor of standard air cooled sockets. Another problem with conventional liquid thermal management systems is that they do not have an industry form factor as air cooled systems do.

In these respects, the liquid thermal management socket system according to the present invention substantially departs from the conventional concepts and designs of the prior art, and in so doing provides an apparatus primarily developed for the purpose of thermally managing an electronic device in a socket.

BRIEF SUMMARY OF THE INVENTION

In view of the foregoing disadvantages inherent in the known types of liquid thermal management systems now present in the prior art, the present invention provides a new liquid thermal management socket system construction wherein the same can be utilized for thermally managing an electronic device in a socket.

The general purpose of the present invention, which will be described subsequently in greater detail, is to provide a new liquid thermal management socket system that has many of the advantages of the liquid thermal management systems mentioned heretofore and many novel features that result in a new liquid thermal management socket system which is not anticipated, rendered obvious, suggested, or even implied by any of the prior art liquid thermal management systems, either alone or in any combination thereof.

To attain this, the present invention generally comprises a thermal management unit having a chamber for receiving one or more electronic devices, a plurality of first connectors within the thermal management unit for electrically coupling with the electronic device, and a plurality of second connectors electrically coupled to the first connectors, wherein the second connectors extend from the thermal management unit for electrically coupling within a socket unit on a board. The thermal management unit may have a cap member attachable to a base portion in a sealed manner. The chamber within the thermal management unit may thermally manage an electronic device within via spray cooling, liquid immersion or other liquid cooling method.

There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof may be better understood, and in order that the present contribution to the art may be better appreciated. There are

additional features of the invention that will be described hereinafter and that will form the subject matter of the claims appended hereto.

In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of the description and should not be regarded as limiting.

A primary object of the present invention is to provide a liquid thermal management socket system that will overcome the shortcomings of the prior art devices.

A second object is to provide a liquid thermal management socket system for thermally managing an electronic device in a socket.

Another object is to provide a liquid thermal management socket system that can be utilized within air cooled sockets.

An additional object is to provide a liquid thermal management socket system that reduces the costs of utilizing liquid thermal management systems.

A further object is to provide a liquid thermal management socket system that does not require any modifications to a board or a socket.

Another object is to provide a liquid thermal management socket system that can be utilized with respect to various electronic device and socket coupler systems.

Other objects and advantages of the present invention will become obvious to the reader and it is intended that these objects and advantages are within the scope of the present invention.

To the accomplishment of the above and related objects, this invention may be embodied in the form illustrated in the accompanying drawings, attention being called to the fact, however, that the drawings are illustrative only, and that changes may be made in the specific construction illustrated and described within the scope of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Various other objects, features and attendant advantages of the present invention will become fully appreciated as the same becomes better understood when considered in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the several views, and wherein:

FIG. 1a is a side view of a conventional socket unit with an electronic device coupled to the socket unit along with a heat sink.

FIG. 1b is an upper perspective view of a conventional socket unit attached to a circuit board.

FIG. 2 is an exploded upper perspective view of the present invention.

FIG. 3 is an exploded upper perspective view of the present invention with respect to a socket unit.

FIG. 4 is an upper perspective view of the present invention coupled to a socket unit (not seen) on a board.

FIG. 5 is a side view of the present invention coupled to a socket with an electronic device contained within.

FIG. 6 is an exploded side view of the present invention with respect to a socket unit.

FIG. 7 is a side cutaway view of the present invention utilized in a spray cooling application.

FIG. 8 is a side cutaway view of the present invention utilized in a liquid immersion application.

FIG. 9 is an upper perspective view of the base portion.

FIG. 10 is a side view of the base portion.

FIG. 11 is a side cutaway view of a device connector coupled within a first connector of the base portion.

FIG. 12 is a perspective view of the inner portion of the cap member containing a raised vapor management protrusion.

FIG. 13 is a perspective view of the inner portion of the cap member containing a raised fluid management protrusion.

FIG. 14 is a perspective view of another embodiment of the present invention wherein the base portion is directly mounted to the board.

FIG. 15 is a block diagram illustrating the fluid connection between the thermal management unit and a liquid thermal management system.

DETAILED DESCRIPTION OF THE INVENTION

A. Overview

Turning now descriptively to the drawings, in which similar reference characters denote similar elements throughout the several views, FIGS. 3 through 15 illustrate a liquid thermal management socket system **10**, which comprises a thermal management unit **20** having a chamber **50** for receiving one or more electronic devices **16**, a plurality of first connectors **32** within the thermal management unit **20** for electrically coupling with the electronic device **16**, and a plurality of second connectors **34** electrically coupled to the first connectors **32**, wherein the second connectors **34** extend from the thermal management unit **20** for electrically coupling within a socket unit **14** on a board **12**. The thermal management unit **20** may have a cap member **40** attachable to a base portion **30** in a sealed manner. The chamber **50** within the thermal management unit **20** may thermally manage an electronic device **16** within via spray cooling, liquid immersion or other liquid cooling method.

B. Thermal Management Unit

The thermal management unit **20** has a chamber **50** capable of receiving one or more electronic devices **16** (e.g. semiconductor chips, microprocessors, integrated circuit devices, power conversion devices, laser diodes, memory devices, etc.) as shown in Figures 7 and 8 of the drawings. The chamber **50** is fluidly connected to a liquid thermal management system **60** where a liquid coolant is applied (spray form, liquid immersion, etc.) to the electronic device **16** for thermally managing the electronic device **16**. Thermal management of the electronic device **16** may include maintaining, lowering or increasing the temperature of the electronic device **16**.

The thermal management unit **20** may be comprised of various structures capable of receiving and thermally managing one or more electronic devices **16**. For

example, the thermal management unit **20** could be comprised of a structure with an electronic device **16** permanently and non-removably positioned within the chamber **50**.

Figures 2 through 8 illustrate the usage of a base portion **30** and a cap member **40** removably attachable to the base portion **30**. The cap member **40** and the base portion **30** together form the chamber **50** where the electronic device **16** is positioned and thermally managed as shown in Figures 7 and 8 of the drawings. Additional discussion regarding the base portion **30** and the cap member **40** is below. It can be appreciated that various other structures may be utilized to construct the thermal management unit **20** other than shown in the figures and that the scope of the present invention should not be limited solely to the structure shown in the figures.

The thermal management unit **20** has a plurality of first connectors **32** positioned within the chamber **50** of the thermal management unit **20** as best illustrated in Figures 2, 3 and 9 of the drawings. The first connectors **32** may be electrically coupled to device connectors **19** of an electronic device **16** as shown in Figure 11 of the drawings. The first connectors **32** may be comprised of a pin grid array, a land grid array or a ball grid array or other connection structure capable of electrically communicating with an electronic device **16**.

The thermal management unit **20** has a plurality of second connectors **34** as best illustrated in Figures 6 and 10 of the drawings. Each of the second connectors **34** are electrically coupled to the first connectors **32** as best illustrated in Figure 11 of the drawings. The second connectors **34** extend exteriorly of the thermal management unit **20** for electrically coupling to at least one socket unit **14** or directly to a board **12**. The second connectors **34** may be comprised of a pin grid array, a land grid array or a ball grid array or other connection structure capable of electrically communicating with a board **12**.

The second connectors **34** may correspond to the position of the first connectors **32** as shown in Figure 11 of the drawings. As further shown in Figure 11 of the drawings, the first connectors **32** may correspond to the position of the device connectors **19** of the electronic device **16**.

C. Base Portion

The thermal management unit **20** may be comprised of a combination base portion **30** and a cap member **40**. The base portion **30** comprises a floor **38** and a sidewall **39** forming a cavity as best illustrated in Figures 7 and 8 of the drawings. The cavity is sufficient in size and shape to receive at least one electronic device **16** as illustrated in Figures 3, 7 and 8 of the drawings. The base portion **30** may have various shapes and structures other than illustrated in the drawings.

A seal **36** is preferably positioned between the edge of the base portion **30** and the edge of the cap member **40** for sealing the chamber **50** between thereof as shown in Figures 7 and 8 of the drawings. Various seal **36** structures may be utilized to seal **36** the cap member **40** to the base portion **30** as can be appreciated.

The first connectors **32** and the second connectors **34** may be attached within the floor **38** as shown in Figure 11 of the drawings. The first connectors **32** and the second connectors **34** are each correspondingly coupled together as further shown in Figure 11.

Figures 2 and 9 illustrate the first connectors **32** as having a receptacle structure in a pin grid array for receiving device connectors **19** comprised of a pin structure or related structure. As stated previously, the first connectors **32** may also be comprised of various other structures (e.g. raised structures, etc.) capable of usage in a ball grid array, land grid array and other connection systems for electronic devices **16**. It can be

appreciated that the base portion **30** may include a retaining structure to retain the electronic device **16** within the base portion **30** such as but not limited to levers, fasteners and snaps.

Figures 6 and 10 of the drawings illustrate the second connectors **34** as having a pin structure for electrically coupling within socket receptacles **15** of a socket unit **14**. As stated previously, the second connectors **34** may also be comprised of various other structures (e.g. raised structures, etc.) capable of usage in a ball grid array, land grid array and other connection systems for electronic devices **16**.

Alternatively, the second connectors **34** may be electrically and physically coupled to a board **12** similar to the connection between a conventional socket unit **14** and a board **12**. Various connection methods may be utilized to connect the second connectors **34** directly to the board **12** such as but not limited to pins soldered into the board **12**, ball grid arrays and land grid arrays.

D. Cap Member

The cap member **40** is attachable in a sealed manner to the base portion **30** as illustrated in Figures 7 and 8 of the drawings. The cap member **40** may have various shapes and structures other than illustrated in the drawings.

The cap member **40** may be manufactured to dispense the liquid coolant (dielectric or non-dielectric) in either a spray cooling or liquid immersion application. Figures 7 and 12 illustrate utilizing the cap member **40** to dispense the liquid coolant in a spray cooling thermal management method. One or more nozzles **43** are positioned within the cap member **40** for spraying the coolant upon the electronic device **16**. The coolant may be atomized through the nozzles **43** as illustrated in U.S. Patent No. 5,860,602 and U.S. Patent No. 6,016,969. The thermally conditioned liquid coolant enters the inlet port **41** and is then dispensed into the chamber **50** upon the

electronic device **16** by the nozzles **43**, thermally conditions the electronic device **16** through liquid immersion and then exits through the exit port as waste coolant to be thermally conditioned by the liquid thermal management system **60**. As shown in Figure 12 of the drawings, a vapor management protrusion **46** may be utilized within the cap member **40** to manage the vapor generated within the chamber **50**. U.S. Patent No. 5,220,804 illustrates a suitable vapor management protrusion **46**. It can be appreciated that the inlet port **41** and the outlet port **42** may be positioned in various locations within the thermal management unit **20** such as also the base portion **30** and any combination thereof.

Figures 8 and 13 illustrate utilizing the cap member **40** to dispense the liquid coolant in a liquid immersion thermal management method. The thermally conditioned liquid coolant enters the inlet port **41** into the chamber **50**, thermally conditions the electronic device **16** through liquid immersion and then exits through the exit port. As shown in Figure 13, the cap member **40** may include a liquid management protrusion **48** that directs the liquid coolant in a path that reduces stagnation locations, such as a spiral pattern. It can be appreciated that the inlet port **41** and the outlet port **42** may be positioned in various locations within the thermal management unit **20** such as also the base portion **30** and any combination thereof.

Figure 8 illustrates the usage of an encapsulant **44** between the electronic device **16** and the base portion **30** to prevent a non-dielectric coolant from making contact with the first connectors **32** and the device connectors **19**. The encapsulant **44** can also be applied to surround and encase the first connectors **32** and the device connectors **19** (not shown).

E. Liquid Thermal Management System

The liquid thermal management system **60** is fluidly coupled to the chamber **50** for thermally managing an electronic device **16** by applying a liquid coolant to the

electronic device **16**. The liquid coolant may be comprised of a dielectric or non-dielectric depending upon the electronic device **16** being thermally managed. The liquid thermal management system **60** may be comprised of spray cooling or liquid immersion.

Applicant hereby incorporates by reference the following U.S. patents: U.S. Patent No. 5,220,804 for a high heat flux evaporative cooling system; and U.S. Patent No. 5,860,602 and U.S. Patent No. 6,016,969, each for a laminated array of pressure swirl atomizers. Although a laminated pressure swirl atomizer array is hereby incorporated by reference, the present invention is not limited to such an apparatus, in fact, many dispensing means are applicable to the present invention including but not limited to inserted atomizers, jet orifices and incremental sprayers.

The liquid thermal management systems **60** described herein include a pump, tubing, and the means for removing heat from a cooling fluid (e.g. heat exchanger). These components are necessary for the operation of a liquid thermal management system **60** but are widely understood in the field, and thus will not be covered in detail. Configurations and details of the above components are not necessary for one skilled in the art to understand the present invention.

F. Operation of Present Invention

In use, the user may first electrically couple the thermal management unit **20** within one or more socket units **14** within a board **12** (or directly to the board **12**) and then position the electronic device **16** within the thermal management unit **20**. Alternatively, the electronic device **16** may be first positioned within the thermal management unit **20** (sealed or non-sealed) and then later install the thermal management unit **20** to the board **12** which does not require further explanation.

When electrically coupling the thermal management unit **20** to a socket unit **14**, the user first aligns the second connectors **34** with the socket receptacles **15** of the socket unit **14** as shown in Figure 3 of the drawings. The user then presses the thermal management unit **20** so that the second connectors **34** are electrically coupled within the socket receptacles **15** of the socket unit **14**.

After the thermal management unit **20** is properly seated upon the socket unit **14**, the user then positions one or more electronic devices **16** directly above the first connectors **32** so that the device connectors **19** correspond to the first connectors **32** as shown in Figure 2 of the drawings. The user then presses the electronic device **16** downwardly into the base portion **30** of the thermal management unit **20** so that the device connectors **19** electrically couple with the first connectors **32** within the thermal management unit **20**. Various mechanical devices may be secured to maintain the electronic device **16** in the desired position. An encapsulant **44** may be added about the electronic device **16** and/or first connectors **32** and device connectors **19** if desired.

The cap member **40** is then attached in a sealed manner to the base portion **30** as shown in Figures 4 and 5 of the drawings. The thermal management unit **20** is then fluidly connected to the liquid thermal management system **60** as shown in Figure 15 of the drawings.

The electronic device **16** may then be activated which generates heat (or heated liquid coolant may be first applied to the electronic device **16** to achieve a desired temperature). The electronic device **16** electrically communicates and is communicated to through the electrical connection created between the respective device connectors **19**, first connectors **32**, second connectors **34** and the socket receptacles **15**.

The thermally conditioned liquid coolant is applied to the electronic device **16** within the chamber **50**. After the liquid coolant is heated (or cooled) from the electronic device **16**, the waste coolant is then returned to the liquid thermal management system **60** for thermal conditioning and cleaning. It can be appreciated that the above method of use can be utilized in conjunction with pin grid arrays, ball grid arrays, land grid arrays and other connection systems.

As to a further discussion of the manner of usage and operation of the present invention, the same should be apparent from the above description. Accordingly, no further discussion relating to the manner of usage and operation will be provided.

With respect to the above description then, it is to be realized that the optimum dimensional relationships for the parts of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed to be within the expertise of those skilled in the art, and all equivalent structural variations and relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention.

Therefore, the foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.